

# HL-LHC ATLAS 4D tracking

## Project schedule and GNN reconstruction

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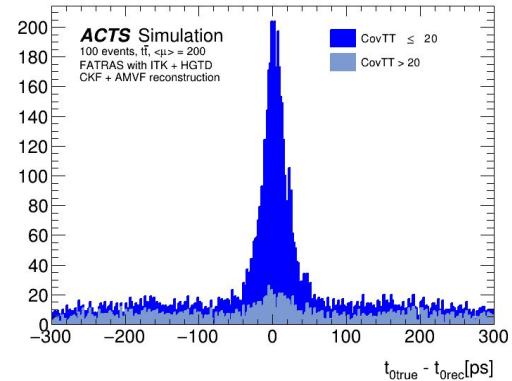
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# Feedbacks on previous presentation

## Feedback:

- Quantify vertices out of the  $\pm \sigma$  in the  $t_0$  reconstruction
  - Compare the bulk of the distribution to the tails
- Evaluate vertex reconstruction residue in function of the multiplicity



## Next steps:

- Evaluate the track efficiency of the proposed reconstruction
  - Need to isolate HGTD track-hit association efficiency
- Get up-to-date sensor degradation information
  - Already talking to the sensor group to get it
- **Optional:** Simulate TDC digitization and uncertainty?

# Revisiting the schedule

Atividade	S.1	S.2	S.3	S.4	S.5	S.6	S.7	S.8	S.9	S.10
Disciplinas do Programa da Pós-Graduação	█	█	█							
Revisão da Literatura	█	█	█	█	█	█	█	█	█	█
Familiarização com os frameworks de reconstrução e análise			█	█						
Implementação dos modelos GNN em reconstrução 3D				█	█					
Preparação para o exame de qualificação					█	█				
Implementação e dos modelos GNN em reconstrução 4D					█	█	█	█		
Introdução da informação de ToT e degradação do sinal dos sensores no modelo								█		
Implementação dos métodos em arquiteturas heterogêneas CPU+GPU								█	█	
Estudo do desempenho da reconstrução (incerteza sistemática, eficiência, desempenho computacional)					█			█	█	
Estágio no CERN (atividades no HGTD e estudos de reconstrução e validação)				█			█	█		
Preparação da Defesa									█	█

- We're  $\approx$  9 months ahead 😊
- There are still plenty of ACTS to uncover, but we need to start shifting gears
- Need to start discussing the implementation of new reconstruction methods

# Research on new methods

- The most prolific collaboration searching for new methods inside ATLAS is the GNN4ITk
  - Don't know of any other
- GNN4ITk acts as an extension of the Exa.trk collaboration ([web page](#)) to apply their solution for ITk
- Would recommend the following readings:

reports, publications & presentations

## Publications

- **Performance of a Geometric Deep Learning Pipeline for HL-LHC Particle Tracking ( Associated Code )** Eur. Phys. J. C **81**, 876 (2021)



most known paper of GNN for tracking

## Conference Contributions

- Hierarchical Graph Neural Networks for Particle Track Reconstruction Presented at ACAT 2022 (Associated Code ).
- **ATLAS ITk Track Reconstruction with a GNN-based pipeline Presented at Connecting the Dots 2022 (Associated Code).**
- Accelerating the Inference Time of Machine Learning-based Track Finding Pipeline Presented at ACAT 2021 ( Associated Code ).
- Graph Neural Network for Large Radius Tracking Presented at ACAT 2021
- Graph Neural Network for Object Reconstruction in Liquid Argon Time Projection Chambers Presented at CHEP 2021
- Distributed Training of GNNs on HPCs Presented at the 4th Inter-experiment Machine Learning Workshop ( Associated Code ).
- "Track Seeding and Labelling with Embedded-space Graph Neural Networks". Presented at Connecting the Dots 2020 - ( Associated Code ).
- "Graph Neural Networks for Particle Reconstruction in High Energy Physics Detectors". Presented at NeurIPS 2019 Workshop "Machine Learning and the Physical Sciences" - (NeurIPS Poster) ( Associated Code ).



PUB note of GNN4ITk

## Presentations

- **Full-length tutorial on Tracking with Graph Neural Networks (Sep 2023, Heidelberg) Part 1 - Part 2**
- Graph Neural Networks for High Luminosity Track Reconstruction (CERN EP-IT Data science seminar).
- Graph Neural Networks for Reconstruction in DUNE (presented at the Dec 4th CLARIPHY topical meeting).
- Tracking with GNNs (in-depth code walk-through at the 4th Inter-experiment Machine Learning Workshop) (colab notebook) ( Associated Code ).
- Graph Neural Networks for Particle Tracking (A non-specialist introduction to Exa.TrkX tracking models).



most comprehensive summary

# Exa.Trk plugin on ACTS

- ACTS has a plugin to use Exa.Trk GNN reconstruction.
  - Almost sure not adapted to 4D reconstruction as we want
  -

## TO DOs

- To make the plugin work, I'll have to install CUDA
  - If there's no nvidia card, will have to search for another machine to run with (Ixplus?)
- Study the implementation
- Compare the performance with CKF
- How to include time information?

```
from acts.examples.reconstruction import addExaTrkX,
ExaTrkXBackend

if backend == ExaTrkXBackend.Torch:
    modelDir = Path.cwd() / "torchscript_models"
    assert (modelDir / "embed.pt").exists()
    assert (modelDir / "filter.pt").exists()
    assert (modelDir / "gnn.pt").exists()
else:
    modelDir = Path.cwd() / "onnx_models"
    assert (modelDir / "embedding.onnx").exists()
    assert (modelDir / "filtering.onnx").exists()
    assert (modelDir / "gnn.onnx").exists()

s = runDigitization(
    trackingGeometry,
    field,
    outputDir,
    digiConfigFile=digiConfigFile,
    particlesInput=inputParticlePath,
    outputRoot=True,
    outputCsv=True,
    s=s,
)

addExaTrkX(
    s,
    trackingGeometry,
    geometrySelection,
    modelDir,
    outputDir,
    backend=backend,
)

s.run()
```

# Backup